

CLAIMS

What is claimed is:

1. A torque sensor comprising:  
5 a shaft comprising magnetostrictive material;  
a pair of opposite magnet poles defining an axis that is aligned tangentially to  
a circumferential surface of the shaft so as to induce a localized magnetic field in the  
magnetostrictive material between the opposite magnet poles; and  
at least one torque-sensing flux detector positioned to detect a component of  
10 the localized magnetic field which escapes from the magnetostrictive material when  
the shaft is torqued.
2. A torque sensor according to claim 1, wherein the at least one torque-sensing  
flux detector comprises a pair of torque-sensing flux detectors positioned on opposite  
15 sides of the shaft circumferentially displaced from the pair of opposite magnet poles.
3. A torque sensor according to claim 1, further comprising a magnet-monitoring  
flux detector positioned to detect the magnetic field produced by one of the magnet  
poles prior to penetration into the shaft.
- 20 4. A torque sensor according to claim 1, wherein the magnet poles are  
permanent magnet poles.
5. A torque sensor according to claim 1, wherein the magnet poles are electro-  
25 magnet poles.
6. A torque sensor according to claim 1, wherein the shaft is hollow.
7. A torque sensor according to claim 1, wherein the shaft is made substantially  
30 only from the magnetostrictive material.

not clear what element (1) specifies  
specific defects since at least one torque sensing flux detector is present

FOOTNOTES: 11003177-110031

8. A torque sensor according to claim 1, wherein the shaft comprises a main body of non-magnetostrictive material and an outer layer of the magnetostrictive material.

5 9. A torque sensor according to claim 1, wherein the shaft comprises a main body of magnetostrictive or non-magnetostrictive material surrounded by a layer of low permeability material which is in turn surrounded by an outer layer of the magnetostrictive material.

10 10. A torque sensor according to claim 9, wherein the pair of opposite magnet poles are poles of a single magnet.

11. A steering column<sup>NS</sup> having a torque sensor comprising:  
a shaft comprising magnetostrictive material;

15 a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and


at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when  
20 the shaft is torqued.

12. A steering column according to claim 11, wherein the torque-sensing flux detector and the further torque-sensing flux detector are positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.

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13. A torque sensor comprising:

a shaft comprising magnetostrictive material;

 a first pair of opposite magnet poles defining a first axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a first localized magnetic field in the magnetostrictive material in a first circumferential direction;  
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a second pair of opposite magnet poles arranged axially displaced along the shaft from the first pair of opposite magnet poles and defining a second axis that is aligned tangentially to the circumferential surface of the shaft so as to induce a second localized magnetic field in the magnetostrictive material in a second circumferential direction opposed to the first circumferential direction; and

first and second torque-sensing flux detectors positioned to detect first and second components of the first and second localized magnetic fields which escape from the magnetostrictive material when the shaft is torqued.

10 14. A gearbox having a torque sensor comprising:

a shaft comprising magnetostrictive material;

a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

15 at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

15 15. A gearbox according to claim 14, wherein the torque-sensing flux detector and the further torque-sensing flux detector are positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.

16. A torque sensor comprising:

a shaft comprising magnetostrictive material;

25 a pair of opposite magnet poles arranged on one side of the shaft and defining an axis that is aligned substantially perpendicular to a principal axis of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

30 at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

17. A method of sensing torque comprising:

- (a) providing a shaft comprising magnetostrictive material;
- (b) applying an external magnetic field to the shaft using a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles;
- (c) torquing the shaft so that a component of the internal magnetic field escapes from the magnetostrictive material; and
- (d) detecting the escaped component of the internal magnetic field and providing a torque signal responsive thereto.

18. A method according to claim 17, wherein the detecting of the escaped component of the internal magnetic field is performed using a pair of torque-sensing flux detectors positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.